PICES Scientific Report No. 28
2005

REPORT OF THE STUDY GROUP ON FISHERIES AND ECOSYSTEM RESPONSES TO RECENT REGIME SHIFTS

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January 2005
Secretariat / Publisher
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3. Implications for the Management of Marine Resources

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3.1 Introduction

There has been much discussion recently on the need for ecosystem assessment and ecosystem-based fisheries management (ESA 1998; FRCC 1998; NMFS 1999; Brodziak and Link 2002; FAO 2003; Garcia *et al*. 2003). Often these two terms have been used interchangeably. However, they do reflect different approaches. Ecosystem assessment is relatively well defined and includes monitoring climate–ocean indices and indicator species to detect ecosystem changes, *i.e.*, assessing the state of the environment. It is important to note that fisheries agencies currently do not manage ecosystems, rather they manage the human impacts on ecosystems. As such, ecosystem-based fisheries management reflects the incorporation of knowledge of the state of the ecosystem (*i.e.*, the ecosystem assessment) into single species assessments when making management decisions. This approach has recently been referred to as Ecosystem Approaches to Fisheries (FAO 2003; Browman and Stergiou 2004). It is an approach that explicitly accounts for ecosystem processes when formulating management actions which may still encompass traditional management tools, such as total allowable catch, but which will likely be different quantitatively as a result of taking account of more factors (Sissenwine and Murawski 2004). Ecosystem-based fisheries management provides a framework for managing marine resources that can consider climate regimes and regime shift impacts on marine ecosystems.

Agencies charged with fisheries management should develop policies immediately which will explicitly specify decision rules and subsequent actions to be taken in response to preliminary indications that a regime shift has occurred. These decision rules need to be included in long-range policies and plans. Management actions should consider the life history of the species of interest, and can encompass varying response times, depending on the species' lifespan and rate of production. The provision of stock assessment advice needs to indicate explicitly the likely consequences of alternate harvest strategies to stock viability, under various recruitment assumptions.

3.2 Response Time of Biota to Regime Shifts

Marine organisms have evolved life history strategies to cope with variability in their environment. These life history strategies range from short-lived, highly variable stock dynamics, which respond immediately to changes in their environment, to extremely long-lived species whose population dynamics are mainly stable (King and McFarlane 2003).

Short-lived species have a shorter generation time which helps to maximize their intrinsic rate of population growth, despite typically having relatively low fecundity. Longevity allows a species to persist through prolonged periods of poor productivity (Leaman and Beamish 1984; McFarlane and Beamish 1986). Long-lived species are typically highly fecund, which allows them to take immediate advantage of changes to more productive regimes, through increased year class success. It is important to note that the intrinsic rate of population growth in long-lived species is lower than in short-lived species, so improved year class success translates into delayed increases in population productivity.

3.3 Response Time of Management to Regime Shifts

Since most fisheries are conducted on mature fish, the age of recruitment to the fishery typically corresponds to the age of maturity. It is possible to use the age of maturity as an indication of how long fisheries managers have to respond to a shift in productivity. For example, Pacific cod matures and recruits to the fishery at age 2+. A shift in productivity, reflected in year class success, would have impacts on the available biomass within 3 years, *i.e.*, this is when a strong year class will appear as a large increase in biomass for the fishery. Conversely, a large year class in a rockfish species would not appear as an increase in biomass to the fishery for 8–10 years (depending on the species). The response time of management actions to regime shifts may be lagged by a correspondence to the age of recruitment of the species of interest.

3.4 Provision of Stock Assessment Advice

Fisheries agencies need to direct fisheries scientists to provide harvest recommendations that reflect a range of risk (low to high) to the stock under different assumptions of productivity or recruitment (*e.g.*, low, medium and high year class success). Different levels of productivity appear to be decadal in nature, corresponding to different regimes, with changes in productivity corresponding to regime shifts (Beamish and Bouillon 1993; Francis and Hare 1994; McFarlane *et al*. 2000; Hare and Mantua 2000; Hollowed *et al*. 2001). Stock assessment scientists should also provide managers with an indication of the most probable productivity level for that particular regime. Managers can make decisions on harvest levels using ancillary information (ecosystem assessments, climate–ocean indices, indicator species) to select the most likely productivity assumption. It is important to note that scientific advice will remain only one of the myriad of factors that managers use to make decisions. Managers will need to consider economic, political and social factors when selecting the appropriate level of risk to the stock that they are willing to accept, and select harvest rates accordingly.

Polovina (2004) reviewed numerous studies that investigate optimum harvest rates for fisheries that are impacted by regime shifts. In some studies, a constant harvest rate strategy generally performed well (Walters and Parma 1996; DiNardo and Wetherall 1999). Polovina (2004) suggested that a constant harvest rate strategy, when applicable, should employ a rate well below traditional benchmarks. However, the preferred strategy is a regime-specific harvest rate (Spencer 1997; Peterman *et al*. 2000; MacCall 2002). For example, a population simulation model of Pacific sardine (*Sardinops sagax*), using a regime-specific harvest rate strategy, produced higher average annual yields and lower variability in spawning biomass than a constant harvest rate strategy (MacCall 2002; Polovina 2004). Improved results could still be achieved even if the switch in harvest rates was delayed some years after the regime shift. However, it should be noted that the simulation assumed regime periods of a known duration, which is not applicable for the current state of knowledge.

In the case of short-lived species that exhibit highly autocorrelated recruitment responses to climate shifts, stock assessment scientists have a high probability of detecting the processes or indices that influence production. Assessment scientists should be directed to incorporate these processes into their assessment advice. When providing advice to managers, stock projections can be conducted, using best estimates of 5- to 10-year climate regimes, to directly incorporate environmental forcing. It should be noted that preservation of spawning stock biomass at levels consistent with maximum sustainable yield (MSY) for a productive period will probably be impossible when the stock shifts to a less productive regime. Minimum stock size thresholds may be the best protection for species with this type of life history strategy. Imposing this type of stock protection will likely result in prolonged periods of no directed harvest during unfavorable regimes.

In the case of long-lived species, the response of the spawning stock biomass to regime shifts will be slower or lagged by the age of recruitment to the regime shift year. For these species, annual recruitment is only a fraction of the spawning stock biomass, and longevity ensures a relatively long reproductive cycle, enabling populations to endure prolonged periods of unfavorable environmental conditions. Maintaining an appropriate age-structure in spawning stock biomass should be a paramount management goal for long-lived, late-maturing species.

In all cases, it is important to maintain a critical spawning biomass. This is a level which ensures that the population is able to withstand long periods of poor environmental conditions. It does imply that exploitation levels may be severely reduced, or in some cases, that no fishing could occur during prolonged periods of poor recruitment.

3.5 Decision Rules

Agencies need to develop policies which explicitly specify decision rules and subsequent actions to be taken in response to preliminary indications that a regime shift has occurred. These decision rules need to be included in long-range policies and plans. Stock assessment advice should provide an indication of the likely consequences of alternate harvest strategies, under various recruitment assumptions, to stock viability. Decision rules must reflect the need to always maintain a critical spawning biomass and a robust age composition. The most appropriate approach to managing fisheries, given regime shift impacts, is to apply regime-specific harvest rates. These harvest rates should be part of the decision rule framework, and should be associated with timeframes for management response triggered when there are indications that a regime shift has occurred. As discussed above, the response time (*i.e.*, changes in harvest rates) can be lagged to correspond to the species-specific biological rates (*i.e.*, age of recruitment) and still enable higher average annual yields and lower variability in spawning biomass. If the regime shift corresponds to an increase in productivity, then delaying the change in harvest rate (from low to high) would allow the population to rapidly increase, resulting in increased recruits under the spawner-recruit relationship of the more productive regime (Polovina 2004). If the regime shift corresponds to a decrease in productivity, then delaying the change in harvest rate (from high to low) and the fishing down of the population will not reduce recruitment under the spawner-recruit relationship of a less productive regime (Polovina 2004). The caveat for delaying a switch from high to low harvest rates in less productive regimes is that aggressive harvest rates could result in a population level that is at, or near, the critical spawning biomass, which could translate into a prolonged period of no fishing. To address this, managers could also consider a provisional step-wise approach to changing harvest rates with regime shifts until the productivity level of a new regime has been verified.

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